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Sudden rise in amplitude of 40 kHz radio signal in relation to solar radio flux

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Abstract The paper reports the experimental observations of isolated short period enhancements in amplitude of 40 kHz radio signal transmitted from Sanwa, Japan to Kolkata, India in relation to solar radio bursts having peak flux greater than 1000 in the unit of 10^{-22} Wm^{-2} Hz^{-1} The delay between commencements of signal amplitude and solar radio bursts lies between 3 and 12 minutes The signal enhancement in dB exhibits linear increase with increase of solar radio flux up to 8000 flux unit The emission of hard X-rays associated with solar radio bursts can cause extra ionization in the D-region of ionosphere As a result, conductivity parameter in wave guide mode theory is changed to allow better reflection This fact is the cause of enhancement of signal amplitude

Keywords Solar radio emission and X-rays, radio propagation, ionosphere.

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1. Introduction

The D-region of the ionosphere, at altitude between 60 and 90 km, is mainly formed due to ionization of nitric oxide (NO) by Lyman-α radiation and from ionization of molecular oxygen (O_2) and nitrogen (N_2) by X-rays of wavelength smaller than 10 A. It is well established [1,2] that L_α radiations and solar X-radiations are closely correlated with solar microwave radiations. So it is expected that D-region of the ionosphere will be appreciably affected due to increase of solar radio emission.

2. Observations and results

The amplitude of 40 kHz radio signal (Call sign : JG2AS/ JJF-2) transmitted from Sanwa, 36°11'N, 139°51'E) has been recorded in a diurnal basis in the Department of Physics, Tripura University. The receiving system consists of loop antenna feeding a number of OP AMPs used in tuned radio frequency mode. The output of AC amplifier and the DC level are further amplified logaritmically. The DC output is used as the signature of amplitude of 40 kHz signal. The overall gain of the amplifier is 120 dB with a band width of 200 Hz. The great circle distance between Agartala (23°N, 91°E) and Sanwa (36°11'N, 139°51'E) is 4884 km.

The amplitude of the recorded signal is larger at night than at day. The sunrise and sunset effects are also characteristic features of the signal. The signal amplitude exhibits enhancement during X-ray flares. Typical *zigzag* variations are also observed due to meteor showers. Quasi-periodic variations are observed during nights followed by high geomagnetic activity.

Apart from all the characteristic variations, it is noted that the signal occasionally exhibits isolated short period sudden enhancements. Isolated in the sense that the signal level is almost straight line within ±2 hours of the event considered. Two samples of events are produced in Figure 1.

During the period from July 1993 to June 1994, we have recorded 57 such events out of which 44 are correlated with outstanding occurrences of solar radio emission of short duration and having peak flux greater than 1000 in the unit

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of 10^{-22} W m^{-2} Hz^{-1}. Solar radio bursts at various fixed frequencies are reported by the worldwide network of

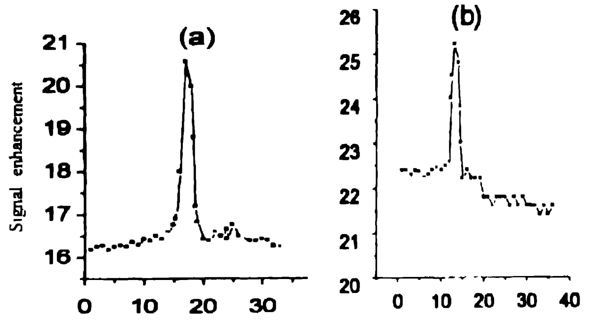

Figure 1. Record of enhancement in 40 kHz signal in relation to solar radio bursts. Signal enhancement is in terms of induced voltage in dB above 1 μV (a) Corresponding to solar burst on 05-10-1993 at 16–47 Hour, IST with peak flux of 1900 unit. The 0-minute corresponds to 16–50 Hour, IST and (b) Corresponding to solar burst on 05-01-1994 at 14–28 Hour, IST with peak flux of 1200 unit. The 0-minute corresponds to 14–15 Hour, IST.

observing stations. The observations are taken from Solar Geophysical Data Book, published by NOAA, US Department of Commerce.

There is a delay in the commencement of sudden enhancement of 40 kHz signal with respect to solar radio bursts. The delay time ranges from 3 mins to 12 mins. The distribution of delay time has been shown in Figure 2. For

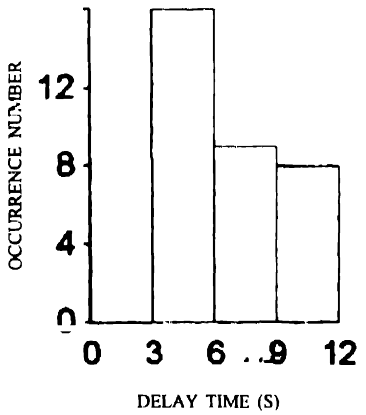

Figure 2. Distribution of signal enhancement events in various ranges of delay time

50% of the events delay times are between 3 mins and 6 mins. The marked feature is that the delay time is at least 3 mins.

The enhancement events related to solar bursts of durations smaller than 5 mins are 32 in number. In this case signal enhancement showed a systematic variation with solar radio peak flux. In Figure 3 we show the variation of signal enhancement with peak flux of associated bursts. The variation exhibits a saturation property after 8000 flux unit. It is worth mentioning that for events related to solar bursts

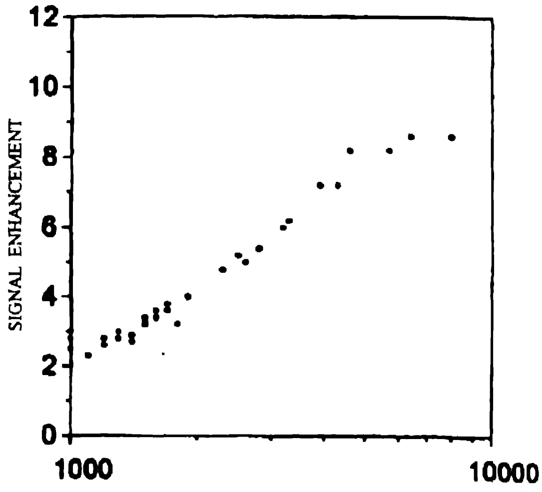

Figure 3. The variation of 40 kHz signal amplitude enhancement (in dB) with the variation of solar radio flux in the 10^{-22} Wm^{-2} Hz^{-1}

of duration greater than 5 mins did not exhibit such graphical relation.

3. Discussion

The dominant process of electron production in the quiescent D-region is the photoionization of nitric oxide by L_α-radiation [3]. Although the contribution of the solar X-rays to the formation of D-region is small, it is established that solar X-rays at $\lambda < 10$ A are certainly responsible for extra-ionization in the D-region [4,5]. The emission of hard X-rays associated with solar radio-burst can cause extra-ionization in the D-region of ionosphere lowering the normal reflection height from 70 km to 60–65 km. There are two competing processes caused by increase in electron density, – *a* decrease in height of the earth-ionosphere waveguide (responsible for sudden decrease in signal amplitude) and an increase in the conductivity of the upper boundary of the waveguide due to steeper electron density gradient which allows better reflection [6]. With respect to wavelength of present signal, the later is dominant and we observe enhancement.

We hilight the fact that enhancement in 40 kHz signal amplitude is only appreciably related with solar radio bursts of small durations, smaller than 5 mins. So it is concluded that association of hard X-rays increases with impulsiveness of solar radio bursts.

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